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1. Your reference	SP/4072 GB	
2. Patent application number *(The Patent Office will fill in this part)*	0226764.9	15 NOV 2002
3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	(1) Alan George Rock 1 Shelley Close Bicester Oxon OX26 2YZ	(2) Angus James Rock 14 Scholar Place Off Arnold Way Cumnor Hill Oxford OX2 9RD
Patents ADP number *(if you know it)*	8507683001	8507691001
If the applicant is a corporate body, give the country/state of its incorporation		
4. Title of the invention	MEASURING DEVICE	
5. Name of your agent *(if you have one)*	STEVENS HEWLETT & PERKINS	
"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	HALTON HOUSE 20/23 HOLBORN LONDON EC1N 2JD	
Patents ADP number *(if you know it)*	1545003	

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
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~~Yes~~ NO (see A/L dtd 28/11/02)

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Continuation sheets of this form	
Description	9
Claim(s)	3
Abstract	
Drawing(s)	5 + 5 8

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Translations of priority documents	
~~Statement of inventorship and right~~ to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature Stevens Hewlett & Perkins Date 15/11/02

12. Name and daytime telephone number of person to contact in the United Kingdom SARAH PERKINS 0207 7404 1955

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DUPLICATE

MEASURING DEVICE

- The present invention relates to a portable self-contained measuring device suitable for measuring the difference in position of two or more points, and preferably but not exclusively for displaying that difference measurement to a user in real time.

As technology has moved on, society has progressed from taking measurements with rulers to using flexible tapes that retract into a small hand-held housing. With the advent of the microprocessor, and miniaturisation of electronics it became possible to take measurements with the use of ultrasonic devices and laser devices.

A straight line ruler is limited by its length. A flexible tape whilst low cost and simple to use is limited by potential variations in reading due to curves in the tape over long distances. The tape is prone to easily breaking, and injuring the user during rapid retraction of the tape into its housing. It is also particularly unwieldy to use over long distances with just one operator.

While the ultrasonic device is quick to use, small, and now relatively cheap to produce, it is limited by the distance it can measure, the requirement to bounce the emitted signal off a parallel surface, and spurious readings due to additional reflective noise. It can also only measure one co-ordinate at a time.

While the laser measuring system is also quick to use and small, and accurate, it is currently expensive to produce. The distance is also limited unless a specific target is used which can allow for increased distances to be measured. It can also only measure one co-ordinate at a time. There are also safety issues relating to products which include laser emitters.

The present invention seeks to provide a new measuring device which is simple to use, portable and at least partially overcomes the problems with known portable measuring devices mentioned above.

The present invention thus provides a portable measuring device comprising: a housing; power supply means; a processor and a plurality of motion sensors adapted to provide a measure of the relative spatial separation of at least first and second locations; a manually or mechanically actuated trigger for identifying at least said first location; and a display for visually presenting information on a measured relative spatial separation.

With the present invention the relative position in 3 axes of measurement, between two points, or between a straight line and a point, or between a flat plane and a point, can be measured and displayed. In a preferred embodiment acceleration, velocity, and translational indications for all six different degrees of freedom are provided by means of electromechanical inertia measuring devices. Furthermore, the measuring device can determine the acceleration due to gravity of the device and can compensate for this background signal. With the preferred embodiment the measuring device includes a series of at least three accelerometers and three gyroscopes to monitor movement of the measuring device in the six degrees of freedom. Ideally the accelerometers and gyroscopes are of MEMS (micro-electromechanical systems) technology to reduce the physical size requirements and to facilitate a lightweight, low power consuming, hand-held device.

Embodiments of the present invention will now be described by way of example with reference to the accompanying drawings, in which:

Fig. 1 is an outline drawing of a first embodiment of the portable measuring device;

Fig 2 is a diagram of a first embodiment of a measurement pointer

Fig 3 is a functional block diagram of a first embodiment of the pcb contained in the portable measuring device;

Fig 4 is a flowchart describing an algorithm to determine when the device is stationary;

Fig 5 is a flowchart describing a method for re-calibrating a stationary device; and

Fig 6 is a flowchart describing a method for re-calculating the current position of the device from the stored trajectory data

A portable measuring device (PMD) is shown in Fig. 1 consisting of a housing 1 in the interior of which is located a plurality of motion sensors in the form of inertial measurement components as a self-contained unit. The inertial measurement components, preferably in the form of an inertial measuring unit (IMU) 2, and their associated electronic interface components are typically prone to drift due to temperature variation. In use, the PMD may be subject to rapid temperature variations e.g. heat from a user's hand. To minimise the effect of a variation in external temperature on the internal components of the PMD, the material of the housing 1 is preferably selected to be thermal insulating and thus have a high thermal

resistance. Also, the housing 1 may be sealed to eliminate variations in internal temperature due to convection.

A measuring point 3 is provided on the exterior of the housing 1 against which all spatial measurements of the PMD are referenced. The measuring point 3 may be an integral part of the housing 1 or may be connected thereto.

The housing 1 of the PMD also includes a trigger 4 which is manually or mechanically actuated. The trigger 4 is connected to a microswitch 5 mounted internally of the housing on a pcb 6. Preferably, the trigger 4 is in close proximity to the microswitch 5 such that each time the trigger 4 is depressed, the trigger 4 activates the microswitch 5 which in turn supplies a signal to a processor 7 also mounted on the pcb 6.

When the PMD is placed against a solid surface to make a measurement, the deceleration force exerted on the IMU 2 may typically be in the order of 10's or 100's of g, and therefore in excess of the measuring range of the IMU 2. To enable the IMU 2 to be able to measure such a deceleration force, a deceleration device 8 (Fig 2) is additionally provided on the housing 1 of the PMD, mounted in a configuration such that in normal operation of the PMD, the deceleration device 8 is the first component of the PMD to make contact with a location surface from or to which measurements are to be made. The deceleration device 8 is preferably compressible and thus provides a means to limit the deceleration force on the IMU 2 to within its measurement range. In this respect the deceleration device may include a compressible material or a compressible element such as a spring. The deceleration device 8 may be an integral part of the housing 1 or may be connected thereto. As illustrated in Fig. 2 in a preferred embodiment the deceleration device 8 and the trigger 4 are combined such that compression of the deceleration device 8 actuates the trigger 4. Of course the deceleration device 8 may be omitted either where the IMU 2 has a measuring range which encompasses the deceleration forces likely to be encountered or where such large deceleration forces do not need to be measured.

The housing 1 also includes a transparent window 9 aligned with a display 10 mounted on the pcb 6. Alternatively, the display 10 may form part of the housing 1. One or more switches in the form of push buttons 11 are provided on the housing 1 (three are illustrated in Fig 1). The push buttons 11 enable a user to control the operation of the PMD. The push buttons 11 are either connected to or mounted in

close proximity to control switches 12 on the pcb 6, such that a respective control switch 12 is activated when a user depresses its associated push button 11.

Turning now to Fig. 3 as mentioned above, a pcb 6 is used to mount and connect the internal components of the PMD. The internal components include the inertial measuring unit (IMU) 2 which is used to provide to a processor 7 electrical signals relating to the positional and rotational movement and orientation of a reference point located within the IMU 2. The processor 7 is programmed with the fixed spatial relationship between the reference point of the IMU 2 and the measuring point 3 on the housing 1 so that the positional and rotational movement and orientation of the measuring point 3 can be determined by the processor 7. Alternatively, each individual inertial measurement component in the IMU may have its own reference point, in which case the processor is programmed with a series of relationships for the spatial difference between the measuring point 3 and each of the individual reference points.

Typically, the IMU 2 contains a plurality of accelerometers and gyroscopes, preferably mounted in the x, y and z axes, which provide electrical signals to the processor 7, proportional to the linear acceleration and rotational velocity of the IMU 2. Alternative embodiments of the IMU 2 may include any combination of motion sensors including but not limited to force measuring devices such as accelerometers and gyroscopes and magnetic field detectors such as magnetometers. Alternative arrangements of the motion sensors, for example in a pyramidal structure, are also envisaged. Whilst the IMU 2 is described as being mounted on the pcb 6, alternative configurations are envisaged which would require additional pcbs or indeed obviate the need for any pcbs. To provide a compact and lightweight structure the IMU 2 is preferably fabricated using MEMS technology such as that described in patents US6,456,939, and US6,295,870 and patent application US2002/0065626.

The IMU 2 may be provided with an additional accelerometer 20, for measuring significantly higher deceleration forces in one axis only. This axis is aligned within the PMD to measure decelerations in the direction of normal motion of the PMD and/or the deceleration device 8 as a user places it against a surface location to be measured. This additional accelerometer 20 may be external to the IMU 2.

A temperature sensor 13 is provided and is connected to the processor 7. The temperature sensor 13 outputs a signal to the processor 7 proportional to the internal

temperature of the PMD. This is used to enable the processor 7 to provide temperature compensation for the signals received from the IMU 2, which are typically temperature dependent. Although illustrated separate from the IMU 2, temperature sensors may be incorporated into one or more of the individual inertial measurement components of the IMU 2 to provide more accurate temperature compensation.

The microswitch 5 which is mounted on the pcb 6 and is activated by the trigger 4 is connected to the processor 7 and outputs an electrical trigger signal to the processor 7 each time the trigger 4 is manually activated by a user or mechanically activated by positioning the trigger 4, or a component such as the deceleration device 8, against a surface.

The processor 7 is also connected to a memory 14. The memory 14 includes 3 alloted memory regions, a first memory region 14a in which the calibration data for the IMU 2 is stored, a second memory region 14b in which reference location data is stored, and a third memory region 14c in which the trajectory data may be stored. The calibration data for the IMU 2 stored in the first region 14a of the memory may be predetermined. Alternatively the calibration data for the IMU 2 may be obtained during the normal operation of the PMD, and stored in the memory 14a.

A display 10 is connected to the processor 7 and is used to continuously display real-time data supplied by the processor 7 on the relative position of the PMD from a previously stored reference location in space which was stored in the reference data memory region 14b.

A power source 15, preferably in the form of a battery, is connected via power supply means to the internal electrical and electromechanical components to supply power for the electronic and electromechanical components. Alternative power sources such as solar cells are also suitable for powering the measuring device.

A clock 16 is connected to the processor 7, and provides a clocking signal to the processor 7, to enable the processor to take successive measurements from the IMU 2 at predetermined regular time intervals, e.g. 1mS to 1000mS. Additionally the processor has access to or includes the functionality of a timer to monitor the time taken for a measurement to be taken. Ideally, the timer is in communication with the clock 16 and consists of an incremental counter 17 which counts the number of clock pulses issued during the taking of a measurement. In this way the number of clock pulses counted is representative of the duration of the measurement. Each time the

trigger 4 is actuated to identify a new 'start point' the counter 17 is preferably re-set to zero. Furthermore, the processor 7 may use the information from the counter 17 to determine an appropriate resolution for the measurement being taken. In this way the resolution of the measurement may be varied in dependence upon the time taken for the measurement which in turn in general may reflect the scale of the measurement (e.g. millimetres, centimetres or metres) or the accessibility of the second location, for example.

One or more control switches 12 are also mounted on the pcb 6 and are connected to the processor 7. The control switches 12 are used to enable a user to select the operation of the processor 7 from a predetermined set of functions, and each control switch 12 supplies a signal to the processor 7 each time the associated push button 11 is pressed by a user. The control switches 12 may be used for example to select whether a measurement is to be made from a point, a line or a plane; the engineering units used to display the measurement e.g. millimetres and centimetres and metres, feet and inches, degrees or angular ratios; the type of measurement to be taken e.g. a first location or second location; how the measurement is to be displayed e.g. as a distance, angle, area or volume. An audible sounder 18 may be provided and connected to the processor 7, and used to provide audible feedback to a user during operation of the PMD.

A port 19 may be provided and connected to the processor 7, and is used to extract the data stored by the processor 7 for further analysis.

When in use, the processor 7 receives signals from the IMU 2, corresponding to the positional and rotational movement and orientation of the reference point in the IMU 2, including device accelerations, angular rates, velocity increments, positional increments and angular increments or to the relative positional and rotational movement and orientation of the reference point in the IMU 2 with respect to an earlier position. It is also envisaged that an IMU might be employed that uses components for providing some but not all of the measurements listed above.

The processor 7 receives an indication from a user by means of one of the control switches 12 that the start of a measurement is to be taken. The processor 7 waits for the trigger 4 to be activated, indicating that the measuring point 3 on the PMD is at the first location referred to as the 'start point', and a user is holding the PMD stationary. The processor 7 is programmed with pre-defined limits of human hand and body movements, and compares these limits with the acceleration and

angular rate parameter values received from the IMU 2 to determine when the PMD is substantially stationary. The flow chart in Fig 4 details an algorithm that may be used to determine that the PMD is stationary. The processor 7 stores all the parameter values generated by or derived from the IMU 2 as a data set into the 'start point' location of the reference location data memory region 14b. The processor 7 resets the velocity and angular rate parameter values to zero, and resets the position co-ordinates of the measuring point 3 on the device to zero. The processor 7 may then activate the audible sounder 18 to inform a user that the 'start point' measurement is complete, and the device can be moved.

As a user moves the PMD, the processor 7 receives new parameter values from the IMU 2. The processor 7 uses these parameter values, together with the corresponding parameter values stored in the 'start point' location of the reference location data memory region 14b, and the known spatial relationship between the measuring point 3 and the centre of measurement of the IMU 2 , to derive a three dimensional spatial difference measurement between the current position of the measuring point 3 and the position at the 'start point'. The processor 7 may in addition derive the difference in both a vertical plane and a horizontal plane between the current and the 'start point' positions of the measuring point 3.

The processor 7 displays the difference measurement to a user on the display 10 in real time such that a user is provided with a continuous and substantially instantaneous display indicating the difference measurement of the measuring point 3 from the 'start point'. In this respect the second location for which a relative measurement from the first location, or 'start point', is required is treated as the instantaneous position of the PMD. However, in an alternative embodiment the trigger 4 may be used to identify for the processor 7 the second location for which a measurement is required in which case a continuously updated real time display is not necessary and instead the measurement is displayed only after the trigger 4 has been actuated to identify the second location. Of course the measurements can be displayed to a user in a number of different formats.

As mentioned earlier, the PMD may also be used to derive and display difference measurements relative to a reference line or a reference plane. Via the control switches 12 a user is able to instruct the processor 7 that additional reference points are to be captured after the first 'start point' measurement has been captured to define a reference line or reference plane. The processor 7 takes a measurement using

the same method as for the 'start point' location, but stores the parameter values generated by and derived from the IMU 2 into a secondary location of the reference location data memory region 14b. The 'start point' location and secondary reference point location can be used by the processor 7 to define a reference line relative to the 'start point', and subsequent difference measurements may be derived and displayed relative to the 'start point' on this reference line. In a similar manner, a third reference point can be captured, to define a reference plane relative to the 'start point', and the processor 7 can derive and display the difference measurements relative to the 'start point' on this reference plane.

When all measurements are complete the data held in the memory 14 may be recalled by a user on the display 10, or downloaded via the port 19 into a computer for subsequent analysis and/or display.

The signals produced by the IMU 2 are prone to drift with both time and temperature which, due to the calculations for translational and angular movement carried out by the processor 7, increases measurement errors with time. To minimise these errors, the processor 7 may adjust the calibration data for each of the sensing elements contained within the IMU 2 stored in the calibration data memory region 14a. Alternatively or additionally, the processor 7 may apply a correction factor to the individual signals received from the IMU 2 or to the calculated relative positional and rotational movement of the measuring point as determined by the processor. One or more means for adjusting the calibration data or measurement signals during normal use of the PMD may be provided in the PMD.

As mentioned earlier, the processor 7 uses the signal from the temperature sensor 13 to determine the internal temperature of the PMD and hence the temperature of the components of the IMU 2. The processor 7 is programmed with a series of temperature related correction factors for each component of the IMU 2, and the processor 7 uses these correction factors to adjust the calibration data for each of the components of the IMU 2 stored in the calibration data memory region 14a at regular time intervals e.g. 1 second to 60 seconds. Alternatively the processor 7 may use the temperature related correction factors to adjust each instantaneous measurement signal received from the IMU 2.

Also, whenever the PMD is determined to be stationary during a 'start point' measurement, certain parameter values generated by, or derived from, the IMU 2 can be assumed to be zero, and the processor 7 can adjust values for the 'start point'

calibration data set stored in the calibration data memory region 14a to remove any offsets for those signals. The flowchart in Fig 5 describes an example of an algorithm for this re-calibration.

Also, whenever the PMD is determined to be stationary other than during a 'start point' measurement, the processor 7 may similarly derive new calibration data for each of the sensing elements of the IMU 2 and store them as a new calibration data set in the next available location in the calibration data memory region 14a.

At the same time as the processor 7 derives and displays the difference measurements, the parameter values generated by, and derived from, the IMU 2 may also be recorded, as a data set, by the processor 7 into the trajectory data memory region 14c at regular time intervals.

The processor 7 uses the sets of calibration data stored in the calibration data memory region 14a, and the sets of parameter values recorded in the trajectory data memory region 14c, and by means of interpolation between adjacent sets of calibration data, derives a new set of calibration data associated with each set of parameter values, and then uses each new set of calibration data and each set of parameter values to re-calculate the relative position of the PMD from the 'start point' to its current position.

The processor 7 uses this revised current position to re-calculate the difference measurement and display it to a user on the display 10. The flow chart in Fig 6 describes an algorithm for this re-calculation.

The trajectory data memory region 14c and the calibration data memory region 14a are over-written with new data each time a new 'start point' measurement is taken.

The nature of the calculations carried out by the processor 7 means that the errors in the measurement accumulate with time. To partially compensate for these errors, the processor 7 can adjust the resolution of the values displayed on the display 10 in relation to the elapsed duration of the measurement. The longer the duration of the measurement, the lower the resolution displayed.

Further adaptations and alterations of the PMD are envisaged without departing from the scope of the invention defined in the appended claims.

CLAIMS

1. A portable measuring device comprising:

a housing;

power supply means;

a processor and a plurality of motion sensors adapted to provide a measure of the relative spatial separation of at least first and second locations;

a user actuated trigger for identifying at least said first location; and

a display for visually presenting information on a measured relative spatial separation.

~~2. A portable measuring device as claimed in claim 1, wherein said housing~~ includes thermal insulation to protect the motion sensors within the housing from variations in external temperature.

3. A portable measuring device as claimed in claims 1 or 2, wherein one or more of said plurality of motion sensors comprises an inertial measuring device.

4. A portable measuring device as claimed in any one of claims 1 to 3, wherein the plurality of motion sensors comprises at least three accelerometers and three gyroscopes.

5. A portable measuring device as claimed in any one of the preceding claims, further including a timer, in communication with the processor, for monitoring the time duration of a measurement wherein the processor is adapted to determine the measure of relative spatial separation to a resolution dependent upon the time duration of the measurement.

6. A portable measuring device as claimed in any one of the preceding claims, wherein the processor is in communication with a volatile memory in which is stored calibration data.

7. A portable measuring device as claimed in claim 6, wherein the processor is adapted to update the stored calibration data whilst a measurement is taking place.

8. A portable measuring device as claimed in any one of the preceding claims, wherein the processor is adapted to determine from information received from the motion sensors when the measuring device is stationary and to generate a positional error correction.

9. A portable measuring device as claimed in any one of the preceding claims, wherein the processor has access to threshold data identifying lower limits of measurable spatial movement representative of small, uncontrolled hand movements of a user.

10. A portable measuring device as claimed in any one of the preceding claims, further comprising a deceleration device for reducing high deceleration forces.

11. A portable measuring device as claimed in claim 10, wherein the deceleration device includes a compressible element.

12. A portable measuring device as claimed in any one of the preceding claims, further including an audible sounder for providing an audible indication of when preliminary measurements at said first or second locations have been recorded.

13. A portable measuring device as claimed in any one of the preceding claims, wherein said power supply means comprises connectors adapted for power connection to a portable power source.

14. A portable measuring device as claimed in claim 13, wherein the portable power source consists of a battery.

15. A portable measuring device as claimed in any one of the preceding claims, wherein the processor is adapted to supply real time data on the relative spatial separation of the measuring device from said first location to said display.

16. A portable measuring device as claimed in any one of the preceding claims, wherein said first location, from which the spatial separation of said second location is determined, is selected from a reference point, a reference line or a reference plane.

17. A portable measuring device as claimed in any one of the preceding claims, wherein the processor additionally includes a data store in which motion data is stored.

Fig 1: Outline drawing of a Portable Measuring Device

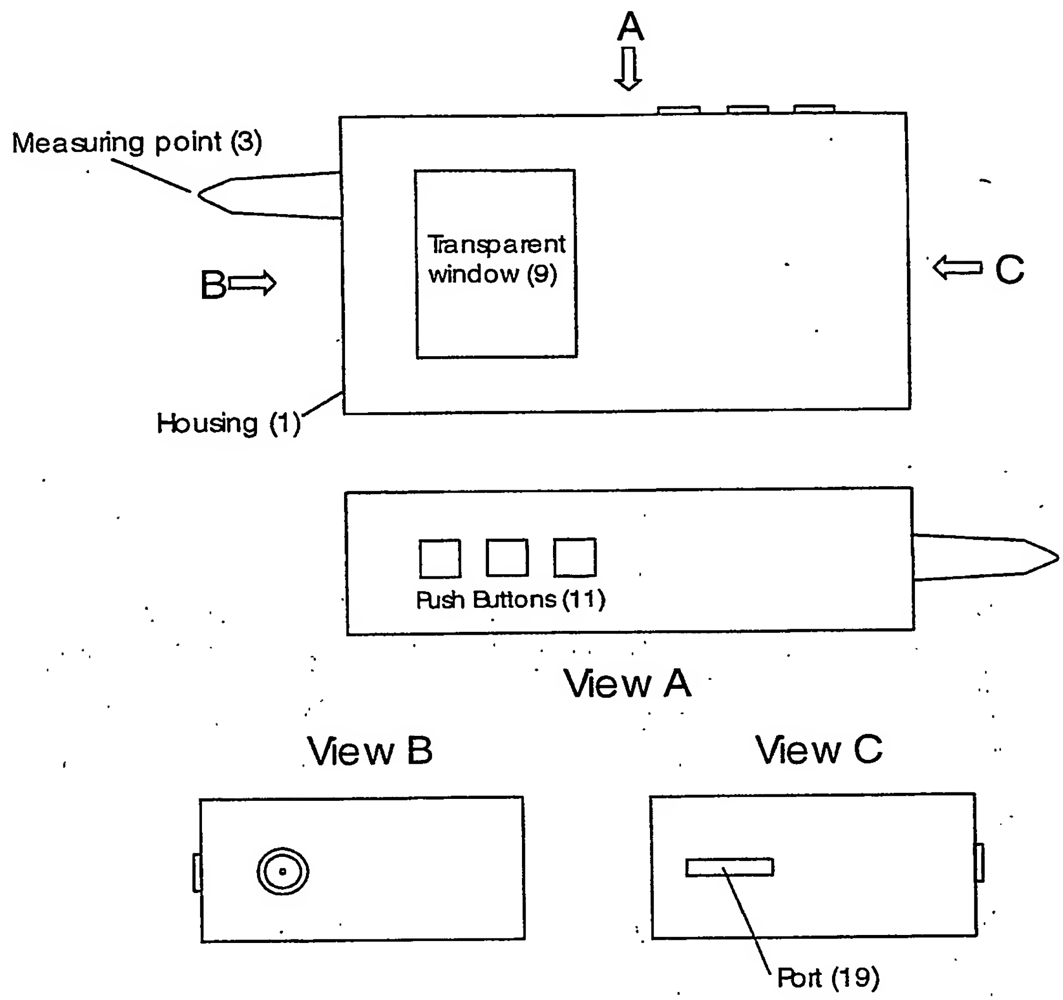

Fig 2: Diagram of a Measurement Pointer combining a measuring point, trigger, and deceleration device.

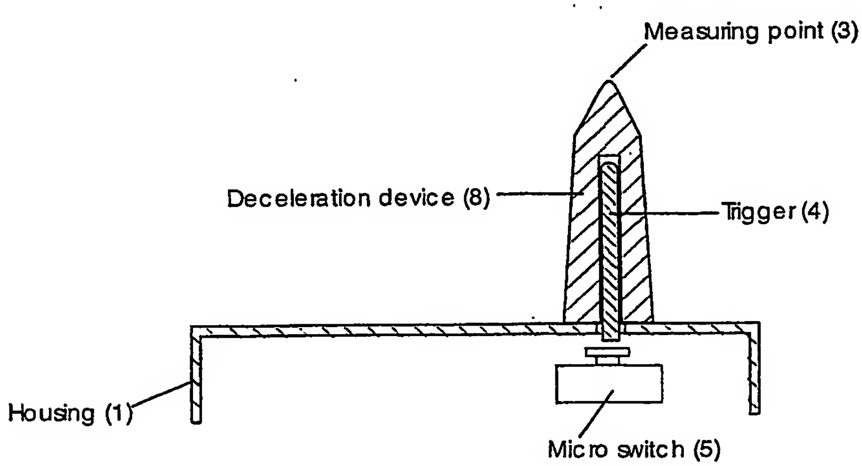

Fig 3: Functional Block Diagram of Circuit Board

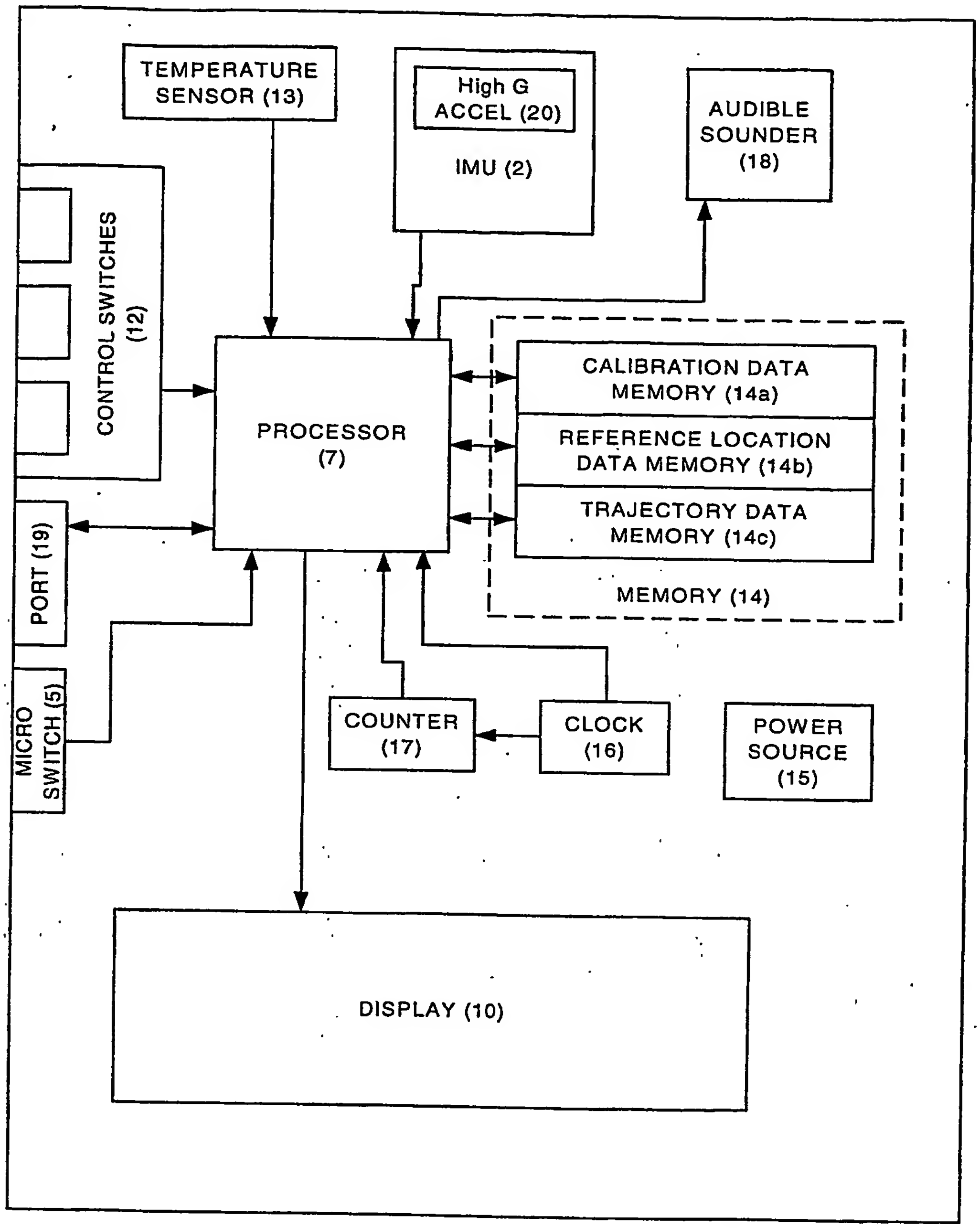

Fig 4 Flowchart for an Algorithm to determine when the device is stationary

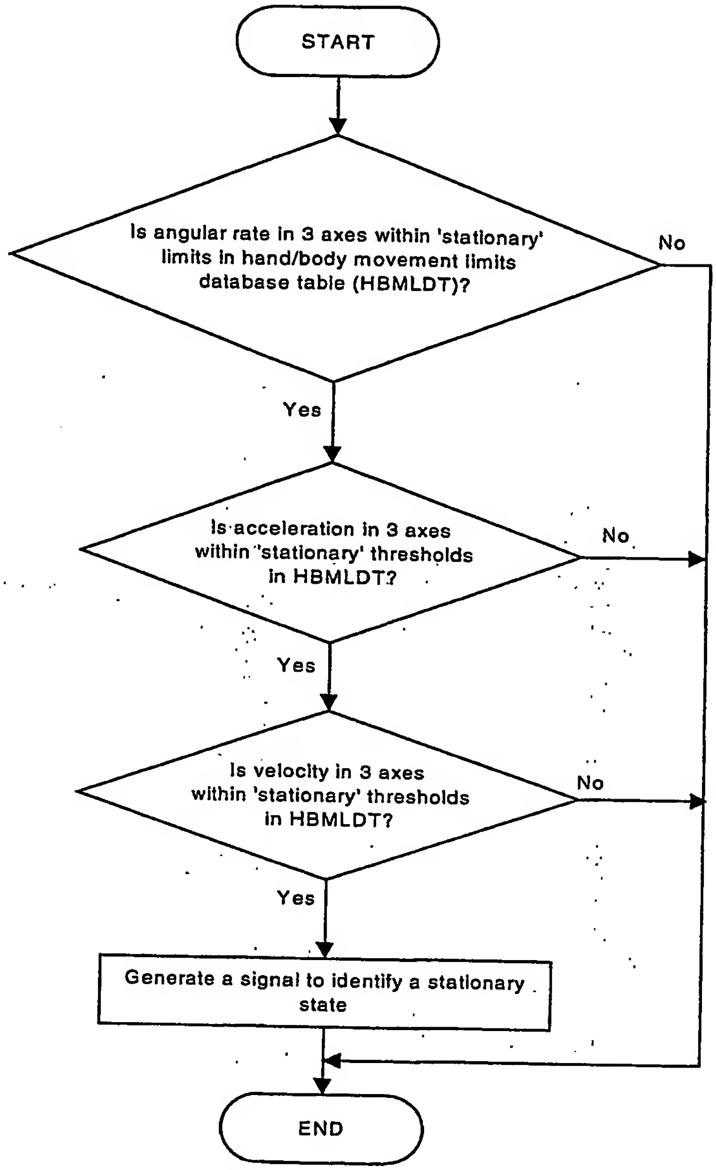

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Fig 5: Flowchart for algorithm to calibrate the device when it is stationary

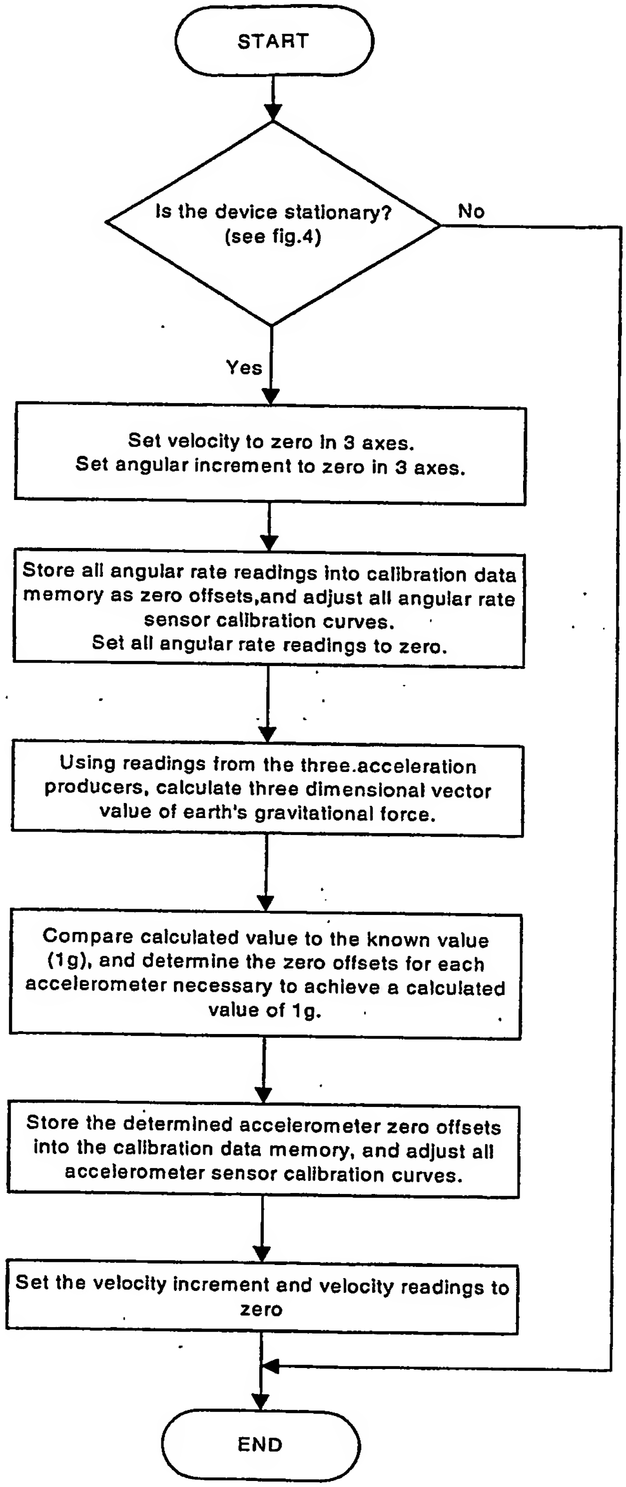

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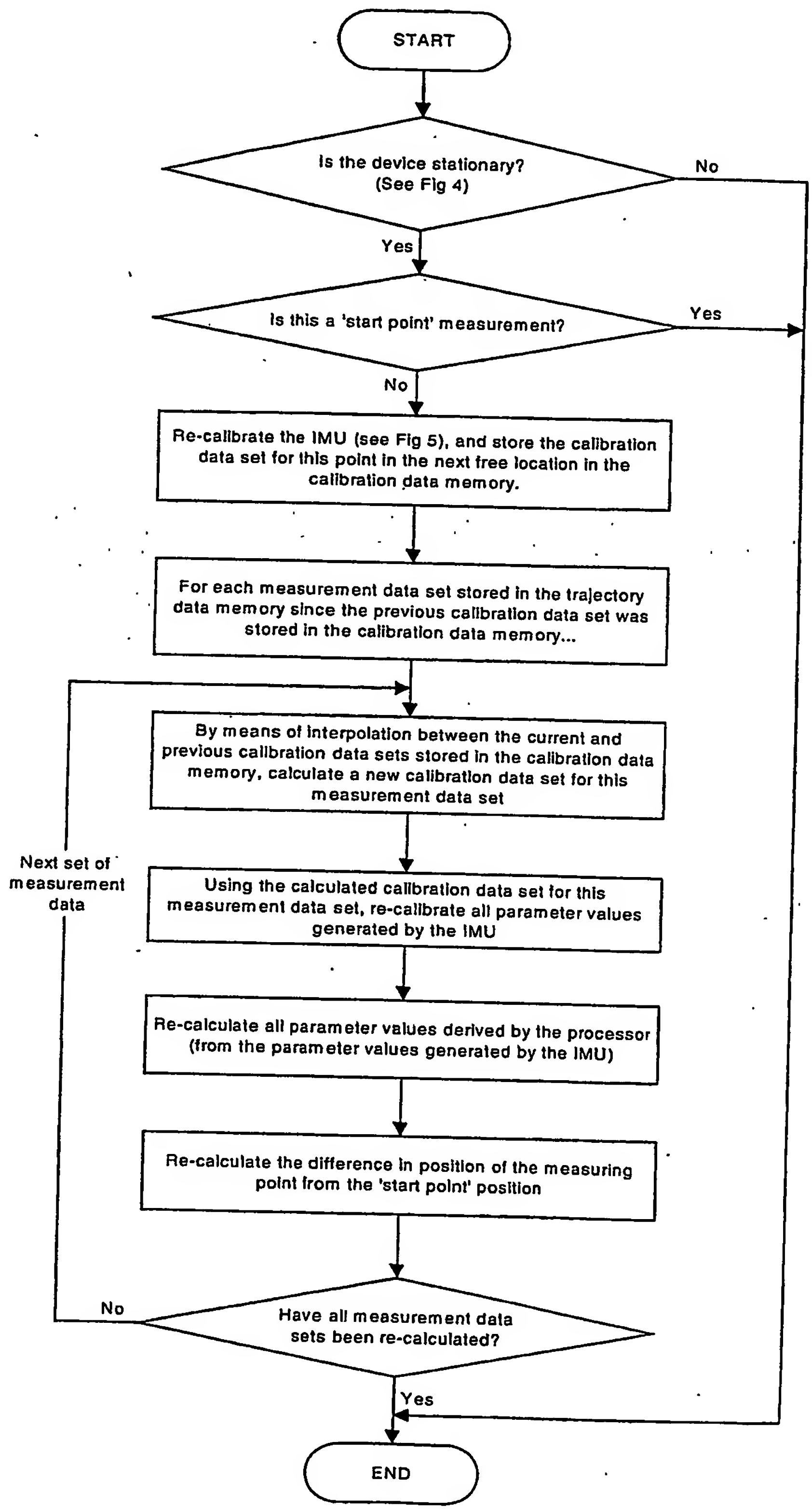
Fig 6: Algorithm for re-calculating the position of the measuring point from stored data, following a re-calibration of the IMU



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PCT Application
GB0304945